Chetco Bar Fire Salvage Project

Soils Resource Report

Rogue River-Siskiyou National Forest

Gold Beach Ranger District

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Introduction

The purpose of this report is to provide soils input into the environmental analysis for the Chetco Bar Fire salvage proposal (Project Area Boundary comprises approximately 143, 047 acres). This analysis will discuss the existing condition, describe the effects of the alternatives, and compare the alternatives. Since management activities, such as fire salvage, can directly impact soil properties, which could remove effective ground, expose bare mineral soil, and reduce soil infiltration capacity, the main issues considered in this analysis are (1) the impacts to soil and site productivity from harvest operations, and (2) changes to soil stability and erosion hazard potential following fire salvage operations.

The **Proposed Action** for the Chetco Bar Fire Salvage project includes approximately: 619 acres of ground based systems harvesting, 2, 378 of skyline systems harvesting, and 1, 093 .of helicopter systems harvesting. Temporary road construction on existing disturbance would entail approximately 12.2 miles. New temporary road construction would entail approximately 1.3 miles. Approximately 103.7 miles of open roads would be used for log haul. An additional 26.4 miles of alternate haul routes have been identified in the event of road failures.

Alternative 3 includes approximately 336 acres of ground based systems harvesting, 1, 244 of skyline systems harvesting, and 288 .of helicopter systems harvesting. Temporary road construction on existing disturbance would entail approximately: 9.4 miles. Approximately 88.6 miles of open roads would also be used for log haul. An additional 26.4 miles of alternate haul routes have been identified in the event of road failures.

Associated road maintenance would also occur within the project area boundary for all alternatives. No road reconstruction is proposed under all Action Alternatives.

Management Direction

The authorities governing Forest Service soil management are outlined in Forest Service Manual (FSM) 2550 – Soil Management (WO Amendment 2500-2010-1, Effective November 23, 2010). Regional direction for maintaining and protecting the soil resource from detrimental disturbance to soil productivity is given in FSM 2500 – Watershed Protection and Management, Region 6 Supplement No. 2500-9801.

The Siskiyou National Forest (SNF) LRMP provides standards and guidelines (S&Gs) for soil and water resources on pages IV-44 through IV-48. In regard to soils and geology, they include S&Gs for detrimental soil conditions, soil erosion, mass movement, and large woody material. Forest- wide standards and guidelines ensure that land management activities shall be planned and conducted to maintain soil productivity and stability (S&G 7-1, pg. IV-44) (SNF, 1989).

On the Siskiyou National Forest, the total area of detrimental soil conditions should not exceed 15 percent of the total acreage within the activity area, including roads and landings (S&G 7-2, page IV-44) (Siskiyou National Forest, 1989). Operations will also be restricted to existing logging facilities (I.e. temporary roads, skid trails, and landings) and roads whenever feasible.

Detrimental soil impacts are defined as those that meet the criteria described in the Soil Quality Standards listed below (Region 6 Supplement No. 2500-9801). In addition, the Region 6 Soil Quality Standards emphasizes that “The cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.” (ibid.).

- Detrimental Soil Compaction in other soils (non-volcanic ash/pumice soils) is an increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macropore space reduction of 50 percent or more, and/ or a reduction below 15 percent macro porosity.
- Detrimental Soil Puddling occurs when the depth of ruts or imprints is six inches or more.
- Detrimental Soil Displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.
- Severely Burned Soils are considered to be detrimentally disturbed when the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next one half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five feet in width.

Surface organic matter (duff, litter) is vital for protecting surface soils from erosion. The SNF LRMP provides standards and guidelines for mineral soil exposure (loss of duff and litter) not to be exceeded on page IV-44 based on each soil’s erosion hazard rate, however due to reduction or loss of the surface OM and canopy interception after moderate and high severity burn, the Chetco Fire Salvage project will be prescribing the most stringent guideline of 85% effective ground cover (EGC) on all soils to mitigate soil disturbance from salvage operations.

Standards and Guidelines for large woody material stress the importance of addressing site-specific needs. In general, five to twenty pieces of large woody material per acre should remain on each site; material should be from a range of decomposition classes; each piece should be at least 20 inches in diameter at the large end and contain at least 40 cubic feet volume (S&G 7-8, pg. IV-45) (SNF, 1989). To better guide site-specific needs, additional tools based on Plant Association Groups (PAGs) and DecAID, an interagency an interagency developed internet-based summary, synthesis, and integration (a "meta-analysis") of the best available science: published scientific literature, research data, wildlife databases, forest inventory databases, and expert judgment and experience, are used to refine the large woody material prescriptions. For more information on DecAID, refer to the Wildlife analysis.

Analysis Methodology

Spatial analysis utilized ArcGIS and the following data layers: 10 meter digital elevation model (DEM), soil burn severity, Soil Survey of Curry County, Oregon (USDA, NRCS 1995), forest service roads, land status/management allocations, aerial photographs, managed stand harvest and burn history output from the FACTS database, and the Oregon Department of Geology and Mineral Industries (DOGAMI) OGDC-5 geographic information systems (GIS) geology layer.

Existing condition values for soil disturbance were obtained from review of aerial photographs using Google Earth Imagery that dated back to 1994, as well as, field review of the project footprint. Existing condition review quantify soil detrimental disturbance, by calculating the average clearing width and length used for past management activities and dividing it by the total area for each unit.

The results are compiled and evaluated against thresholds in the Siskiyou National Forest Plan and the FS Regional Manual to investigate long-term reductions to productivity (*Forest Service manual R-6 supplement no. 2500-9801*). Soils having detrimental disturbance are assumed to have long-term reductions in productive capacity. However, interpretation depends on soil type and environmental setting.

Data to determine the productive capacity and relative sensitives to disturbance (i.e. erosion hazard) from associated activities was generated using soil properties and interpretations from the Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

An erosion hazard assessment was evaluated for each soil map unit in the project footprint for all action alternatives. Acres of harvest units proposed overlapping with severe to very severe erosion hazard ratings (off road/off trail) were calculated to estimate the likelihood for potential erosion. This same method was completed for temporary roads, however, the acreage calculated was based off of erosion hazard (road/trail). Descriptions of what these ratings are based on is described below. Soil map units are described to pinpoint any erosion hazard concerns.

Slope Stability and Erosion Risk Mapping

Modelling was conducted utilizing tools in ArcMap to estimate the relative risk of slopes in the planning area to instability and erosion. Slope gradient, slope aspect, slope curvature, and upslope contributing area were used to model the spatial variability of soil properties. The use of individual terrain attributes have proven useful for soil-landscape modeling and has been demonstrated that landform element classifications can aid in delineating soils (Pennock et al. 1987, Park et al. 2001). This modeling of terrain attributes provides for a site-specific inventory (based on a 10 x 10 meter grid) that was modeled using digital terrain information and modeling tools within ArcMap, a geographic information system (GIS). The base set of data used to model terrain characteristics is a Digital Elevation Model (DEM). These DEMs meet U.S. Geological Survey (USGS) standards for content, format, and accuracy. DEMs for lands in the conterminous United States are produced in a 7.5-minute latitude by a 7.5-minutes longitude quadrangle format, with elevations spaced at 10 meter intervals (horizontally).

The following discusses the tools used in modeling the terrain characteristics used in this analysis. These attributes include slope gradient, slope aspect, slope curvature, and upslope contributing area. Table 1 displays the terrain parameters used to model the risk rating for slope stability and erosion.

The slope gradient tool in ArcMap utilizes the DEM to identify the steepest downhill slope for a location on a surface. Slope gradient was measured as percent slope. Percent slope of an area is a measure of the change in height (elevation over a measured distance). Slope is calculated for each cell in a raster map. It is the maximum rate of change in elevation over each cell and its eight neighbors. The lower the slope value, the flatter the terrain while the higher the slope value, the steeper the terrain.

The slope curvature tool was used as measure of the shape of the slope. The curvature of a surface is calculated on a cell-by-cell basis using a surface composed of a 3 cell by 3 cell window. The output of the curvature model can be used to describe the physical characteristics of a drainage basin in an effort to understand erosion and runoff processes.

A positive curvature indicates that the surface is upwardly convex at that cell. A negative curvature indicates that the surface is upwardly concave at that cell. A value of zero indicates that the surface is flat. Curvature of the slope affects the acceleration and deceleration of flow and, therefore, influences erosion and deposition. In this analysis, curvature was classified based on the the following: Concave slope has a curvature value of < (-3); convex slope has a curvature value of >3; linear slope has a curvature value of (-3) - 3.

Upslope contributing area is also termed “flow accumulation”. The accumulated flow is a value based upon the number of cells flowing into each cell in the raster. The flow accumulation tool utilizes slope aspect to determine the direction of flow for each cell. The results of the flow accumulation tool were then used to create a stream network by applying a threshold value to select cells with a high accumulated flow. This method of deriving accumulated flow from a DEM is presented in detail in Jenson and Domingue (1988). By adjusting the threshold value, the accumulated flow model can identify the areas where streams originate and thus identify headwall areas where instability might be a concern. Table 1 describes the parameters used for modeling within the Chetco Bar Fire Salvage Project.

Table 1. Description of terrain physical parameters used for modelling risk rating.

Terrain Feature	Value	Rating
Curvature	< (-3)	Very High
Slope	> 65% & > 2.5 acres	Very High
Flow Accumulation		
Slope	> 65%	High
Flow Accumulation	> 2.5 acres	High
Flow Accumulation	0.2 – 2.5 acres & 25 – 65%	Moderate
Slope		
Flow Accumulation	< 0.2 acres & < 30 - 65%	Moderate
Slope		
Flow Accumulation	0.2 – 2.5 acres & < 25%	Low
Slope		
Flow Accumulation	< 0.2 acres & < 30%	Low
Slope		

The accuracy of the data used for modeling and analysis under this NEPA analysis is deemed to be adequate. This is supported by field verification of random areas within the project area, and professional opinion based on years of experience on these soil

Spatial and Temporal Scale

Spatial Scale

Slope stability effects focus on areas directly within, and upslope and downslope of proposed activities, since slope stability is affected by actions that would occur directly or immediately adjacent to the slope.

Soil productivity effects focus on soils that are directly within the proposed project footprint, since soils are affected by actions that occur directly upon them.

Cumulative effects use the same treatment unit as reference to estimate the combined effects of past, present, and reasonably foreseeable activities.

Temporal Scale

Slope stability short term effects first 1-3 years; captures direct impacts from vegetation changes or disturbance that can trigger instability due to changes in precipitation/soil interaction on a site. Long term impacts starting at 7 to 10 years; captures changes in root strength on a slope, as roots from cut conifers decay and can cause shallow groundwater piping, etc., and roots from any remaining trees potentially expand in extent.

Soil productivity effects short term effects first 1-5 years, which would include the expected recovery of organic matter and nutrients in soils that have experienced disturbance, such as displacement, erosion, or shallow surface compaction at a level that is not considered detrimental. Long term effects are expected to last 25 years or greater, and refer to soil effects that are considered detrimental, such as deep compaction and extensive displacement and loss of the A horizon.

Affected Environment/Existing Condition

Chetco Bar Fire Salvage Project Soils

Soils within the Chetco Bar Fire Salvage Project Footprint were first mapped as part of the Siskiyou National Forest Soil Resource Inventory (SRI) (Meyer and Amaranthus 1979). The SRI provides soil landtype unit information and interpretations that were specifically geared towards forested landscape management, and this information is still pertinent for forest management today. The area was later mapped by the Natural Resource Conservation Service as part of the Curry County Oregon Soil Survey (USDA, NRCS 1995), providing soil survey data that is consistent with national soil survey standards. This analysis utilizes data generated from the Curry County County Oregon Soil Survey, unless specifically noted.

Soils within the project footprint are developed from metamorphic and sedimentary rocks from the Dothan Formation. The topography of the Dothan Formation varies from low, rolling ground to steep hillslopes as well as prominent ridges and rock outcrops. Soils are mostly in a mesic soil temperature regime, with highest elevations in the frigid soil temperature regime. The areas of low relief are predominantly in mudstone, siltstone, and shale. Soils in mudstone, siltstone, and shale are generally silty and clayey, deep (40 to 60 inches), and poorly drained. Areas of steeper relief are predominantly sandstone or overlaid with sandstone. Soils in sandstone tend to be sandy, well drained, and depths of moderately deep (20 to 40 inches) on slopes to shallow (< 20 inches) on ridges. Dothan volcanics form thin, rocky soils or outcrops.

Figure 1 displays the soil map units and the harvest units proposed for the Chetco Bar Fire Salvage project. Inceptisols and Ultisol soil orders are represented in the project footprint. Inceptisols are soils that generally exhibit only moderate degrees of soil weathering and development. Ultisols are soils that form in humid areas, from fairly intense weathering and leaching processes that result in a clay-enriched subsoil dominated in minerals, which, in some of the ultisols in project footprint area, is kaolinite. Ultisols are typically acid soils in which most nutrients are concentrated in the upper few inches.

Table 2 displays the soil map unit name, approximate acres within the project footprint, and relative sensitivities to disturbance, based off of various soil properties. (Web Soil Survey https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx)

Figure 1. Soil map units within the project footprint of Chetco Bar Fire Salvage project.

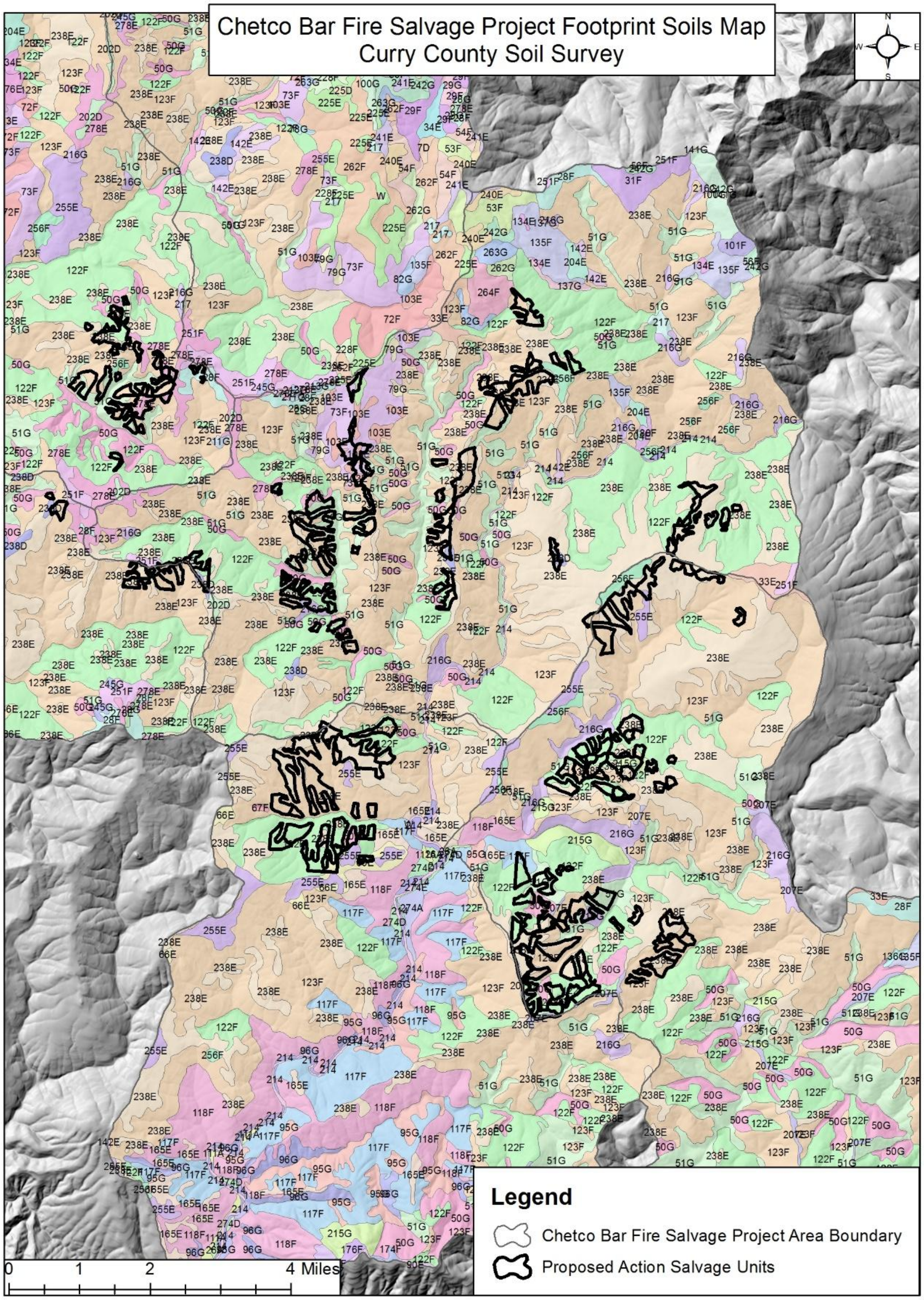


Table 2. Soils within the project footprint of the Chetco Bar Fire Salvage project.

Soil Map Units	Soil Map Unit Name	Acres	Depth to Soil Restrictive Layer (centimeters)	Forest Productivity (Tree Site Index)(feet).	Hydrologic Soil Group	Erosion Hazard (Road/Trail)	Erosion Hazard (Off-Road, Off-Trail)	Soil Susceptibility to Compaction	Dominant Surface Soil Texture
28F	Bobsgarden-Rilea-Euchrand complex, 30 to 60 percent south slopes	1	>200	91	C	Severe	Severe	Medium	Sandy loam to loam
50G	Cassiday-Grouslous-Bravo complex, 60 to 90 percent north slopes	65	97	116	C	Severe	Very Severe	Medium	Sandy loam to loam
51G	Cassiday-Grouslous-Bravo complex, 60 to 90 percent south slopes	243	97	116	C	Severe	Very Severe	Medium	Sandy loam to loam
66E	Crutchfield-Colepoint complex, 15 to 30 percent slopes	20	99	115	C	Severe	Moderate	Low	Sandy loam to loam
73F	Deadline-Barkshanty-Nailkeg complex, 30 to 60 percent south slopes	69	148	108	C	Severe	Severe	Medium	Sandy loam to loam
103E	Edson-Barkshanty complex, 15 to 30 percent slopes	29	188	89	C	Severe	Moderate	Medium	Sandy loam to loam
117F	Floras-Bosland-Dulandy complex, 30 to 60 percent north slopes	8	125	115	C	Severe	Severe	Low	Sand to loam
122F	Fritsland-Bravo-Cassiday complex, 30 to 60 percent north slopes	892	127	126	C	Severe	Severe	Medium	Sandy loam to loam

123F	Fritsland-Bravo-Cassiday complex, 30 to 60 percent south slopes	1, 292	127	126	C	Severe	Severe	Medium	Sandy loam to loam
165E	Loeb-Macklyn complex, 15 to 30 percent slopes	2	122	105	C	Severe	Moderate	Low	Sand to loam
207E	Remote-Digger-Rock outcrop complex, warm, 3 to 30 percent slopes	26	>200	104	B	Severe	Moderate	Medium	Sandy loam to loam
215G	Rock outcrop-Grouslous-Cassiday complex, 60 to 90 percent north slopes	33	0	N/A	N/A	Severe	Very Severe	Medium	Sandy loam to loam
216G	Rock outcrop-Grouslous-Cassiday complex, 60 to 90 percent south slope	33	0	N/A	N/A	Severe	Very Severe	Medium	Sandy loam to loam
225E	Saddlepeak-Threetrees complex, 15 to 30 percent slopes	13	>200	106	C	Severe	Moderate	Low	Loamy sand
238D	Skookumhouse-Hazelcamp-Averlande complex, 0 to 15 percent slopes	30	135	122	D	Moderate	Slight	Medium	Sandy loam to loam
238E	Skookumhouse-Hazelcamp-Averlande complex, 15 to 30 percent slopes	1, 269	135	122	D	Severe	Moderate	Medium	Sandy loam to loam
251F	Stackyards-Rilea-Yorel complex, 30 to 60 percent north slopes	1	117	82	C	Severe	Severe	Medium	Sandy loam to loam

255E	Swedeheaven-Quailprairie-Sankey complex, 0 to 30 percent slopes	7	69	N/A	C	Moderate	Moderate	Low	Sand to loam
256F	Swedeheaven-Quailprairie-Sankey complex, 30 to 60 percent south slopes	3	69	N/A	C	Severe	Severe	Low	Sandy loam to loam
278E	Zalea-Pyrady-Yorel complex, 15 to 30 percent slopes	55	89	85	C	Severe	Moderate	Medium	Sandy loam to loam

The following sections give a brief explanation of each rating, summarized from the Descriptions in the Web Soil Survey. Refer to the complete descriptions for more detail.

Forest Productivity

The "site index" is the average height, in feet, that dominant and codominant trees of a given species attain in a specified number of years. Within the project footprint the dominant tree measured for site index is Douglas Fir, and the site index base was developed following James E. King (1966 (795)) .The site index applies to fully stocked, even-aged, unmanaged stands. A "representative" value indicates the expected value of this attribute for the component, and is how it is described in the table above. Soil map units are rated by using the ranges below in the Web Soil Survey, as shown in Table 3.

Table 3. Ranges used to rate forest productivity in the Web Soil Survey for the project footprint.

Soil Rating Polygons
<= 82
> 82 and <= 91
> 91 and <= 108
> 108 and <= 119
> 119 and <= 126
Not rated or not available

The site index within the project footprint ranges from 82 to 126 feet. However, the dominant soils (soil map units: 122F, 123F, and 238E) is high. All soils within the proposed units, with the exception of a few small, shallow, rocky inclusions, support forest vegetation.

Erosion Hazard (Off Road/Off Trail)

Ratings indicate the hazard of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface. Ratings are based on slope and soil erosion factor K, with soil loss caused by sheet or rill erosion where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance.

The dominant erosion hazard off road/ off trail for soils ranges from moderate to severe. This is due to moderate to steeper slopes and soils with hydrologic group C and D ratings. Hydrologic Soil Groups are a useful index reflecting a soil's inherent potential for runoff and erosion.

- Hydrologic Group A- Low runoff potential when thoroughly wet. Water is transmitted freely through the soil. These soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- Hydrologic Group B- Moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. These soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- Hydrologic Group C- Moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- Hydrologic Group D: High runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters (20 inches) and all soils with a water table.

Erosion Hazard (Road/Trail)

Ratings indicate the hazard of soil loss from un-surfaced roads and trails. Ratings are based on soil erosion factor K, slope, and content of rock fragments. "Slight" indicates that little or no erosion is likely; "Moderate" indicates some erosion is likely, and roads/trails may require occasional maintenance, and that simple erosion-control measures are needed; "Severe" indicates that erosion is expected, roads/trails require frequent maintenance, and costly erosion-control measures are needed.

The dominant erosion hazard on road/ trail for soils is severe. This is due to the high clay content of most subsurface horizons, which limits water movement through the soils. Runoff from these soils is common. Project Design Criteria described in Chapter 2 of the Environmental Assessment (EA) would reduce the likelihood of erosion in skid trails within these units, thus reducing the risk of overland flow and erosion. Proper surface drainage is also necessary on all roads and skid trails that cross these soils. Temporary roads would be subject to compaction and runoff when wet, increasing the potential for erosion. Operations timed to coincide with the dry soil moistures is the best options for these soil types.

Soil Susceptibility to Compaction

Soils are rated based on their susceptibility to compaction from the operation of ground-based equipment for planting, harvesting, and site preparation activities when soils are moist. Interpretation ratings are based on soil properties in the upper 12 inches of the profile. Factors considered are soil texture, soil organic matter content, soil structure, rock fragment content, and the existing bulk density.

Definitions of the ratings:

- Low - The potential for compaction is insignificant. This soil is able to support standard equipment with minimal compaction. The soil is moisture insensitive, exhibiting only small changes in density with changing moisture content.
- Medium - The potential for compaction is significant. The growth rate of seedlings may be reduced following compaction. After the initial compaction (i.e., the first equipment pass), this soil is able to support standard equipment with only minimal increases in soil density. The soil is intermediate between moisture insensitive and moisture sensitive.
- High - The potential for compaction is significant. The growth rate of seedlings will be reduced following compaction. After initial compaction, this soil is still able to support standard equipment, but will continue to compact with each subsequent pass. The soil is moisture sensitive, exhibiting large changes in density with changing moisture content.

The dominant rating for soil susceptibility to compaction within the project footprint is medium. The remaining soils are categorized as low. Therefore, soil compaction would be low and further reduced if design criteria is followed during operations. Project design criteria such as, designating skid trails and temporary roads prior to operations and harvesting during dry soil moisture conditions have been developed to mitigate these disturbances.

Mass Failure

To identify soils that may be prone to mass failure, the SRI was utilized. The SRI characterized landtype units 8 and 9 as landflow and landslump terrain derived from sedimentary rocks. These landtypes tend to have slopes that are benchy and hummocky, which is evidence there has been past or present movement. Other areas of mass movements in the watershed are concentrated in the inner gorges and tributary headwalls underlain by Dothan mudstone, siltstone, and sandstone units and in contact zones.

However, the majority of proposed ground-based, mechanized treatments are planned for areas with slopes less than or equal to 30 percent, which greatly reduces the risk of mass failures. The occurrence of any mass failure activity as a result of implementation of any of the activities is unlikely because potentially unstable or unstable areas would be avoided during layout and implementation as described in the project design criteria in Chapter 2.

Soil Disturbance Evaluations

Past forest management activities have affected soils in the project area boundary through compaction, displacement, removal of organic matter, burning, and erosion. Based on agency records, approximately 12, 703 acres (9 percent) of the project area boundary has had previous harvest entries. Past management included clear cuts, precommercial thinning, salvage cuts, thinning for hazardous fuels reduction, planting, and commercial thinning. These activities date back to the 1954 through 2009. Clear cuts occurred in the 1960s through 1980s. A potential for soil restoration activities exists in areas that have had past management.

Table 4 summarizes existing condition disturbance values for proposed units within the project footprint. This method was not uniformly reliable as the canopy cover, where dense, would obstruct the view. In these cases, additional percentages were added for detrimental compaction, puddling, burning, and soil displacement based on stand management history recorded in agency files (FACTS database). The extent of ground disturbance within proposed activity areas is moderate to low and currently well below the limits of the Siskiyou National Forest Plan standard of 15% for maintaining soil productivity with the exception of units: **29 and 166**. In activity areas where more than 15 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move conditions toward a net improvement in soil quality, as per Region 6 soils policy (***Forest Service manual R-6 supplement no. 2500-9801)***.In addition, harvest units that are approaching the threshold for detrimental soil conditions are: **39, 81, 93, and 144**. These units will also be highlighted in the project design criteria to avoid exceeding limits set in the SLRMP and moving these sites towards a net improvement in soil quality over time. All units not listed, which includes both natural stands and managed stands with treatment activities that created light disturbances have a DSD of zero percent from past harvest activities. .

Table 4.Proposed treatment units estimated existing disturbance within the Chetco Bar Fire Salvage Project.

EA Unit Number	Acres	Area of Existing Soil Disturbance Prior to Salvage	
		Unit Acres	Percent of Unit
29	13.2	2.7	20
30	52.3	2.3	4.4
31	39.1	2.1	5.4
35	34.0	1.7	5.0
36	8.5	0.5	5.9
37	9.6	0.7	7.3
38	21.0	0.2	1.0
39	3.7	0.4	11.0

40	**12.1**	**0.3**	**2.5**
45	**7.0**	**0.2**	**2.9**
47	**48.9**	**1.7**	**3.5**
48	**15.0**	**0.3**	**2.0**
50	**31.0**	**0.8**	**2.6**
52	**3.9**	**0.2**	**5.1**
53	**46.7**	**0.2**	**0.4**
54	**10.9**	**0.4**	**3.7**
56	**15.5**	**0.5**	**3.2**
59	**10.6**	**0.4**	**3.8**
60	**18.0**	**0.4**	**2.2**
61	**40.1**	**1.8**	**4.5**
62	**21.6**	**0.3**	**1.4**
63	**26.8**	**0.2**	**0.7**
64	**20.6**	**1.3**	**6.3**
66	**22.0**	**0.2**	**0.9**
67	**39.2**	**3.6**	**9.2**
69	**8.8**	**0.3**	**3.4**
70	**26.2**	**1.7**	**6.5**
72	**19.3**	**1.2**	**6.2**
73	**78.6**	**0.9**	**1.1**
74	**49.5**	**1.2**	**2.4**
79	**149.7**	**4.3**	**2.9**
80	**30.2**	**0.2**	**0.7**
81	**40.8**	**4.1**	**10.0**

83	**16.5**	**0.2**	**1.2**
84	**29.4**	**0.5**	**1.7**
87	**63.7**	**5.0**	**7.8**
88	**23.9**	**0.9**	**3.8**
89	**20.6**	**0.2**	**1.0**
93	**16.7**	**2.2**	**13.2**
94	**37.1**	**0.5**	**1.3**
95	**23.5**	**0.7**	**3.0**
96	**36.9**	**1.5**	**4.1**
97	**50.6**	**2.2**	**4.3**
99	**30.0**	**0.8**	**2.7**
102	**5.5**	**0.3**	**5.5**
104	**25.7**	**0.8**	**3.1**
105	**20.3**	**1.9**	**9.4**
106	**36.1**	**1.6**	**4.4**
108	**13.4**	**0.6**	**4.5**
109	**8.3**	**0.6**	**7.2**
111	**80.3**	**0.6**	**0.7**
112	**37.9**	**2.1**	**5.5**
113	**13.5**	**0.2**	**1.5**
114	**37.9**	**1.3**	**3.4**
116	**27.8**	**1.6**	**5.8**
117	**64.0**	**0.7**	**1.1**
118	**27.7**	**0.2**	**0.7**
121	**28.6**	**1.8**	**6.3**

125	51.4	2.2	4.3
128	5.1	0.2	3.9
129	9.9	0.5	5.1
131	10.0	0.2	2.0
133	8.4	0.5	6.0
135	44.8	2.1	4.7
138	36.7	0.9	2.5
139	57.2	0.2	0.3
140	55.4	2.8	5.1
141	83.7	5.4	6.5
142	57.4	3.2	5.6
144	10.4	1.0	10.0
145	40.7	2.6	6.4
146	27.7	0.3	1.1
147	24.1	0.9	3.7
148	26.4	1.6	6.1
149	25.1	1.6	6.4
154	83.5	0.8	1.0
160	57.9	4.0	6.9
162	6.2	0.2	3.2
166	30.5	5.5	18.0
169	22.3	0.8	3.6
173	31.8	0.8	2.5
175	58.7	1.9	3.2
176	46.4	2.4	5.2

177	**101.9**	**3.8**	**3.7**
179	**74.5**	**1.0**	**1.3**

Fire

The Chetco Bar Fire is the most recent, large-scale disturbance in the project area boundary, and effects from the fire are discussed throughout the existing condition, environmental consequences, and cumulative effects sections. This analysis uses post-fire burn severity to describe potential watershed effects of the fire, and potential interactions with treatments in the Chetco Bar Fire Salvage Project area. Soil burn severity is the effect of fire at and below the ground surface, specifically how the fire changes the physical and chemical composition of the soils. Fire severity that detrimentally effects soil conditions leads to further degradation of soil productivity and soil-hydrologic function.

Existing condition of soils burned in the Chetco Bar Fire is based on the Final Soil Burn Severity map developed during the Chetco Bar Fire BAER assessment. Details of how that assessment and the final map was developed can be found in the *2017 Chetco Bar Fire BAER soils report.*

The ERMiT estimates from the BAER assessment were generated for each soil map unit and burn severity, and apportioned to watersheds on a per-acre basis. The ERMiT model refines estimates by incorporating customized climate parameters that are initially based on readings from local weather stations. Model output was in tons per acre on a *5 year storm event* basis, so these are not annual estimates. Maximum sediment delivery rate modeled was 96.8 tons per acre. However, accuracy of model output is estimated to be +/- 50%.

The proposed salvage project is located on the western perimeter of the wildfire. Burn conditions are largely high and moderate burn severity within proposed treatment units. Soils burned at these severities would take longer to recover than low burn severity due to the consumption of organic matter and soil surface experiencing high temperatures. However, the model may have over predicted sediment delivery rates based on observations made from recent and this winter’s field visits. Within low and moderate burn severities a layer of needle and leaf litter (i.e. “needle cast”) has begun accumulating from scorched canopy and increasing groundcover. Resprouting of vegetation, such as tanoak, pacific madrone, evergreen huckleberry, ferns, beargrass, bigleaf maple, and other understory vegetation, has been noticed in all burned severity types, including what was classified as high burn severity. In high burn severity sites the groundcover and future leaf litter will be important contributions to prevent future soil erosion and begin the soil recovery processes. Additionally, there was no evidence of soil movement being transported long distances. Generally, localized sheetwash is getting intercepted by the uneven terrain and large decaying logs are limiting long distance transport. No gullies have been observed due to post-fire conditions, however rilling on road cutbanks of hillslopes have been noticed due to bare soil conditions on these sites. Localized pedestalling under the dripline of dead trees has also been noted on burned soils.

Following the 2002 Biscuit Fire, soil erosion monitoring was conducted in order to document the effects of fire on surface erosion in areas of high and low burn severity, in addition to other objectives set by the Siskiyou N.F. (GSA & Geocorps, 2005). Results were concluded based on 240 sediment plots installed before the first winter storms. Sites were based on various soil, geologic, and landscape characteristics as well as previous management history and burn severity. The monitoring studies found: plots showed either erosion or net accumulation of soil, needle cast and leaf litter appeared to have the greatest effect on erosion vs accumulation and percent slope on similar burn severities had a greater affect to erosion rates (GSA & Geocorps, 2005). Additionally, over three winter seasons there did not appear to be a significant increase in soil movement due to the fire (GSA & Geocorps, 2005).

The fire affected 29 percent of the proposed treatment acres at high burn severity, and of that 4 percent is ground based harvest systems. See Table 5 and Figure 2.

Table 5. High severity burn acres within harvest units for Chetco Bar Fire Salvage project.[1]

Unit	Acres	Harvest Method	High Burn Severity Acres
6	46.7	Skyline	1.0
7	3.9	Skyline	2.7
12	10.6	Skyline	5.6
13	18.0	Skyline	5.5
14	21.6	Tractor	5.7
16	26.8	Skyline	10.8
17	9.9	Skyline	5.1
21	39.2	Tractor	3.8
22	28.8	Tractor	0.2
23	22.0	Skyline	0.6
24	11.0	Skyline	3.1
25	20.6	Skyline	18.6
26	39.1	Skyline	37.3
27	9.6	Skyline	5.6
29	21.0	Tractor	0.3
32	5.5	Skyline	2.5
33	34.0	Skyline	8.3
34	4.5	Tractor	4.5
35	2.8	Tractor	2.1
36	1.6	Tractor	1.0
37	5.2	Skyline	1.0
38	19.8	Skyline	1.2
39	52.3	Helicopter	27.8

[1] **If the harvest unit is not mentioned in Table 4, high soil burn severity was not mapped within the proposed treatment areas.**

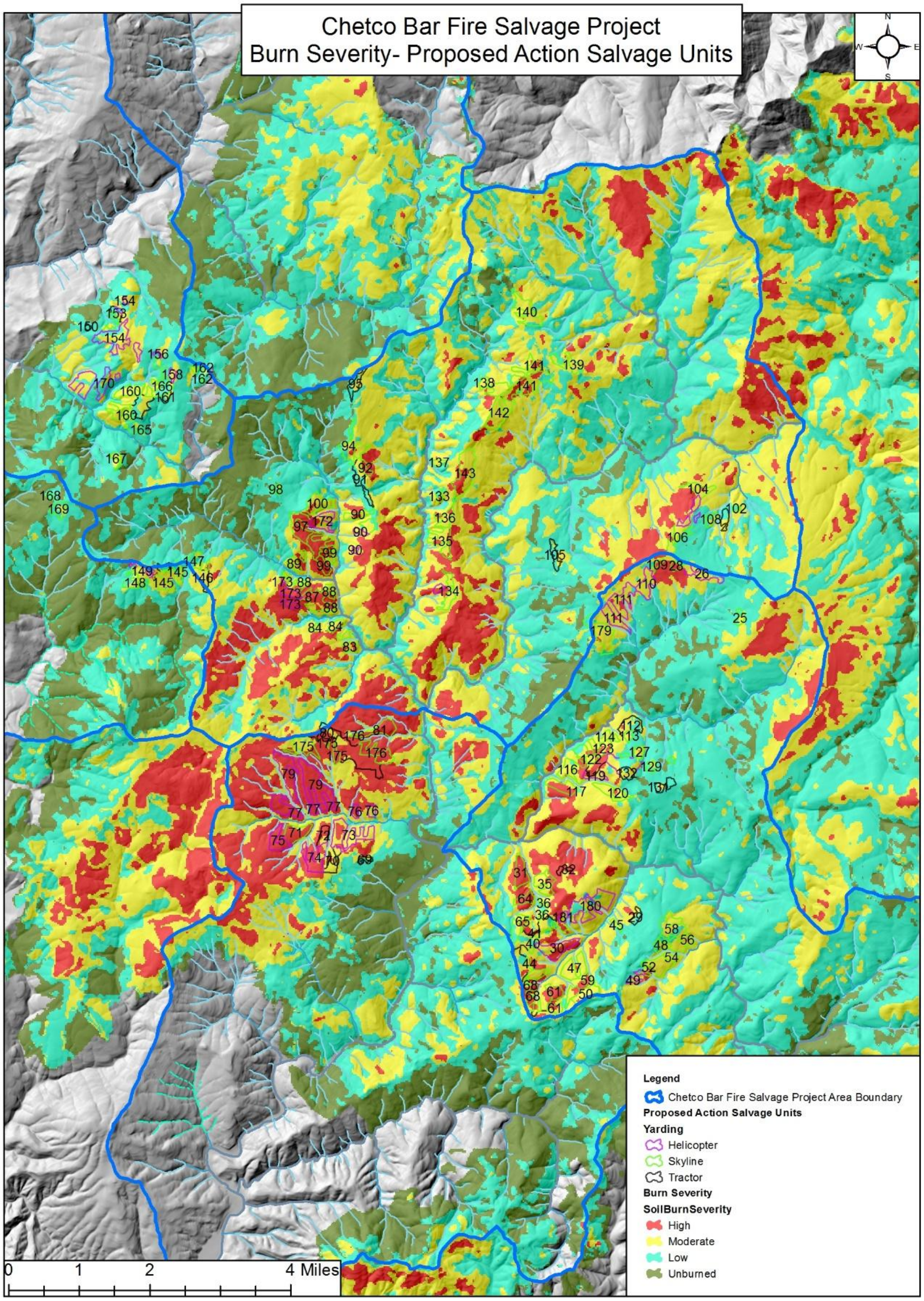
40	8.8	Tractor	0.1
41	26.2	Tractor	2.6
42	78.6	Helicopter	18.5
43	19.3	Tractor	13.9
44	44.4	Skyline	39.5
45	149.7	Helicopter	138.5
46	35.6	Helicopter	35.4
51	10.1	Helicopter	10.1
52	8.6	Helicopter	8.6
53	10.2	Helicopter	10.2
54	40.8	Skyline	38.2
55	16.5	Skyline	6.2
57	63.6	Skyline	41.8
59	20.6	Skyline	4.2
85	35.8	Helicopter	0.9
86	11.8	Skyline	8.0
88	40.0	Skyline	4.8
93	16.7	Skyline	1.1
96	36.9	Skyline	35.2
98	50.6	Skyline	43.4
104	25.7	Skyline	2.8
106	36.1	Skyline	1.2
107	23.9	Helicopter	2.6
109	8.3	Skyline	4.3
110	38.0	Helicopter	0.9
111	74.5	Skyline	1.7
112	37.9	Tractor	1.3

114	37.9	Skyline	3.9
115	27.8	Skyline	0.4
116	36.1	Skyline	22.6
118	27.7	Skyline	12.4
119	14.6	Helicopter	4.3
120	12.4	Skyline	2.4
121	28.6	Tractor	23.5
122	10.3	Skyline	1.6
123	20.9	Skyline	8.7
124	51.4	Helicopter	0.2
125	17.9	Skyline	0.2
129	10.0	Tractor	1.1
132	57.2	Skyline	2.9
133	57.4	Skyline	4.4
136	88.3	Skyline	27.7
138	25.2	Skyline	5.5
139	44.8	Skyline	10.9
140	30.7	Skyline	2.6
142	27.7	Tractor	0.1
143	24.1	Skyline	1.6
147	25.1	Helicopter	0.2
170	35.0	Helicopter	8.9
173	30.2	Tractor	15.4
175	101.9	Tractor	89.3
177	80.3	Helicopter	6.5
178	90.0	Helicopter	1.5
179	10.0	Helicopter	3.3

185	44.4	Skyline	40.3
186	2.0	Skyline	1.8
188	12.0	Skyline	11.9
190	3.1	Skyline	3.1
191	43.7	Skyline	12.4
192	11.3	Helicopter	1.7
194	8.8	Helicopter	7.5
196	33.6	Helicopter	33.3
198	49.5	Helicopter	35.4
201	31.0	Skyline	1.2
203	17.1	Skyline	5.8
204	23.0	Skyline	19.9
206	3.7	Skyline	0.3
208	5.9	Skyline	0.2
244	22.7	Skyline	1.1
249	37.1	Skyline	3.8
251	13.1	Skyline	9.6
256	41.8	Skyline	5.0
258	17.6	Skyline	17.6
260	12.4	Skyline	6.9
262	7.6	Skyline	2.9
265	9.0	Skyline	2.9
266	2.5	Skyline	0.1
270	8.1	Skyline	0.2
272	15.6	Skyline	1.8
274	11.7	Helicopter	11.7
275	17.3	Helicopter	17.3

276	2.8	Helicopter	1.3
277	9.4	Helicopter	5.9
279	8.4	Skyline	1.8
281	83.7	Skyline	31.6
282	25.9	Skyline	1.4

Figure 2. Soil burn severity for proposed salvage units within Chetco Bar Fire Salvage project.



Environmental Consequences

Project Design Criteria/ Best Management Practices/ Mitigation Measures

The following best management practices/mitigation measures/product design criteria are required to ensure compliance with the management direction for the soil resource and/or to reduce the risk of adverse impacts to the soil resource from ground disturbing activities, such as salvage logging, road use, and road maintenance,. A description is provided as to when, where and how the design feature should be applied and/or what conditions would trigger the need to apply the design feature. Table 6 lists the project design criteria (PDC). PDCs can also be found in Chapter 2. Typical BMPs include avoiding equipment operation in wet areas (wetlands, seeps, riparian reserves, etc.), designing road and skid trail systems to prevent or minimize erosion, and proper erosion control measures during road use.

Table 6. Project design criteria/best management practices/ mitigation measures for the Chetco Bar Fire Salvage Project.

• Assess sensitive soils to determine if equipment operations can occur without causing excessive soil disturbance. Use the Slope Stability and Soil Risk Erosion model to aid in identifying unstable and potentially unstable terrain. The areas identified as VERY HIGH risk in this analysis are considered unstable or potentially unstable areas, and as such are included in the Riparian Reserve network. Using this process, areas classified as “VERY HIGH” will be excluded from treatment activities and will be buffered appropriately according to the Riparian Reserve widths identified for the Chetco Fire Salvage project. A Hydrologist or Soil Scientist will assist in field validation and identification of additional unstable areas and streams prior to implementation of stand treatments.
• All units were evaluated to determine detrimental soil disturbance levels. Appropriate design features would be implemented in order to ensure units are at or below 15% detrimental soil disturbance per Forest Plan and Regional Standards. Project units **29 and 166** must have no new disturbance and reuse existing templates and disturbances associated with harvest. Active soil restoration methods will be used to improve soil condition. Project units: **39, 81, 93, and 144** will be monitored by Sale Administrator to result in no more than 15% detrimental soil condition as they are approaching Forest Plan S & G’s thresholds. **Roadside Danger Tree Abatement harvest units overlapping with area salvage would be a priority area to evaluate.** Such actions could include scarifying/decompacting soils and placement of slash, woody material and/or duff over exposed soil. Equipment would remain on designated temporary roads and skid trails.
• Ground-based equipment would only operate on slopes less than or equal to 30 percent.
• Scatter generated slash in treatment areas to meet Forest Plan Effective Groundcover S&Gs of 85% ground cover by end of operations, with an emphasis of leaving fines (material less than three inches in diameter) on site.
• Leave LWD dispersed throughout treatment areas, commensurate with LWD guidelines for WL/PAGs & the Forest LRMPs**.** Five to twenty pieces of large

woody material per acre should remain on each site where management activities take place. Material should be from a range of decomposition classes; each piece should be at least 20 inches in diameter at the large end and contain at least 40 cubic feet volume (SLRMP IV-45, S&G 7-8).
• Operation of ground-based harvesting/yarding equipment off road is limited to dry soil moisture conditions, or solidly frozen ground (with or without snowpack). Percent soil moisture levels are to be determined by a Soil Scientist, using standard soils methodology, and will be monitored to avoid detrimental soil impacts. Rutting, caking, smearing, puddling are all indicators of high soil moisture levels.
• Pivoting of machinery should be avoided in order to prevent soil displacement.
• The leading end of logs would be suspended during cable yarding.
• Space ground-based and cable equipment operations to result in no more than 15% of the treatment area resulting in detrimental soil conditions. All skid trails would be designated and laid out to take advantage of topography and minimize disruption of natural drainage patterns. Reuse existing skid trails where possible.
• When skid trails are to be decompacted or subsoiled following ground based harvest and fuel reduction activities in order to reduce compaction and potential for erosion. An excavator or similar equipment with a winged subsoiler attachment should be utilized in order to reduce impacts. Decompaction activities should go no deeper than 20 inches and should avoid mixing the soil layers or disrupting their orientation. Subsoiling should employ a “hen scratch” pattern that avoids creating long furrows that parallel the slope. These activities would be conducted when the soil is dry. In general, operations during the dry period typically occur June 1st to October 31st, but may vary by year, depending on local weather conditions. Effective ground cover requirements (85% EGC) should be left on the skid trails following decompaction. The timber sale administrator, in conjunction with a Forest Service soil scientist would determine those areas that need to be decompacted.
• All landings utilized would be decompacted preferably with an excavator and covered with residual slash (85% EGC).
• No new landings would be allowed within Riparian Reserve. Avoid re-using existing landings near any type of likely flow or sediment transport conduit during storms, such as ephemeral channels and swales, where practicable.
• All temporary roads would be rehabilitated (all new construction would be recontoured; existing prisms would be placed in a stable condition through recontouring and/or decompaction to a minimum depth of 20 inches). Cut/fill slopes would be reshaped to natural contours and crossings removed. Available slash and large wood material (>3 inches) would be applied to the recontour surface. Placement of large logs or boulders would be installed to prevent the use of vehice use. If temporary roads are kept open over winter, drainage work to winterize temporary roads would be completed (i.e waterbars and outsloping).
• Assure that water control structures are installed and maintained on skid trials,

	temporary roads, and landings with spacing requirements appropriate with soil texture and slope percent. Ensure erosion control structures are stabilized and working effectively at all times, and at the end of treatments.
•	Plan pile burning for when soil moistures are high enough to minimize consumption of soil organic matter and minimize soil heating. Minimize the size of individual slash hand piles scattered in the units to less than 10 ft. by 10 ft. Distribute piles to reduce severe burn impacts from concentrated fuel.

Undeveloped Lands

Undeveloped lands within the project footprint were not identified to have special or unique soil resource values. Soils identified within the project footprint are described in Table 2. Effects to the soil resource from proposed project treatment activities would not differ based on the designation of land. Management direction and project design criteria are required to ensure compliance and avoid adverse impacts to soils, and would be implemented during operations across all land designations. Therefore, the description of effects are not differentiated further in the analysis, and include salvage logging activities and the associated connected actions to complete project activities. Approximately, 826 acres (20%) of undeveloped lands are proposed for salvage under Alternative 2, and an estimated 1.5 miles (11%) of existing legacy templates reused for operations as temporary roads.

Logging Systems

Ground Based Harvest Systems

Ground-based logging systems have the greatest potential to adversely affect short and long-term soil productivity. Logging and other equipment can compact and 'puddle' soils over which they operate (landings, skid roads, roadways, etc.). Tractor, or ground based logging has the greatest potential to cause soil compaction, which decreases soil volume and pore space and modifies soil structure and results in a decrease in gas, water, and nutrient exchange, slows root penetration, and can aggravate soil drought, especially in Mediterranean climates such as that of SW Oregon (Atzet et al., 1989), though soil drought may be less of a concern here where there is a much stronger maritime weather influence. Puddling is the destruction of soil structure, primarily when wet, by severe compaction, to the point where ruts or imprints are made and the soil structure has been so destroyed as to prevent water from infiltrating into the soil profile.

Compaction may inhibit occupation of the soil by organisms that assist in the decomposition of wood to soil organic material that improves site productivity, and help to aerate the soil. Compaction also possibly inhibits the growth of beneficial fungi (mycorrhizae) that provide nutrients to plant roots (Keslick, 1997). Ectomycorrhizal fungi form an essential interface between soil and trees. They usually colonize more than 90 percent of the feeder roots of host plants (Goodman and Trofymow, 1998). Plant development is also restricted in compacted soils due to poor aeration and impeded root growth. As a result, soil productivity is adversely affected (Floch, 1988).

Soil moisture content, soil characteristics, and force affect the level of compaction that can occur from harvest systems. Fine-textured soils dominated by expandable clay minerals, and well-graded, coarser textured soils are most likely to compact when moist, whereas finer textured soils dominated by non-expandable clay minerals, and of poorly graded, coarser textured soils such as most pumice and coarse ash soils, are less affected by soil moisture (Atzet et al, 1989).

Compaction from logging activities is now routinely mitigated, by designating and minimizing the number of skid trails used; by requiring logging equipment to use only those roads and skid trails created during past timber harvest where feasible; using equipment and or techniques shown effective to prevent or minimize compaction (such as operating on slash to disperse weight); and allowing operations only during conditions when soils are unlikely to be detrimentally compacted beyond the 15% LRMP allowances (such as on dry or frozen ground; or over deep snow with a firm base). These mitigations have been proven successful and are applied to all Action Alternatives in this project

Detrimental displacement is defined as the removal of more than 50% of the soil's 'A' horizon (topsoil) from an area greater than 100 square feet that is at least 5 feet in width. This displacement occurs by natural means, such as heavy rains that cause erosion on exposed surfaces (such as skid trails and skyline corridors), or by mechanical means such as churning tractor treads or dragging of logs across the ground. Erosion is a form of detrimental displacement. The majority of erosion occurs by sheet erosion (the even removal of thin layers of soil by water moving across extended areas of gently sloping land) and is difficult to detect, as there are no dramatic effects to alert one to its occurrence. Rills and gullies, however, are dramatic examples of erosion that are easily detected.

Detrimental displacement is routinely mitigated by designating and minimizing the number of skid roads and skyline corridors used; requiring a minimum of one-end log suspension to prevent soil gouging; and placing percent slope limitations on ground-based harvest equipment. Additionally, erosion associated with skid trails and skyline corridors can be effectively mitigated by the placement of cross drains (water bars); drainage dips; placement of down wood and slash; and erosion control seeding (or any vegetative cover on exposed soil). Mitigation measures specifically designed for this project can be found in Chapter 2.These measures have been used for many decades and there has been considerable monitoring and demonstration of their effectiveness.

Large woody material, such as large logs, and standing snags (future large down logs), are important components in the development and retention of productive soils. Snags are routinely felled if they are believed to be a safety hazard to operations. Operation of logging equipment can mechanically damage/destroy downed logs in advanced stages of decay. Logging and burning has the potential to eliminate these features, particularly those in advanced degrees of decay, from the landscape if care isn't taken to retain them in adequate sizes, numbers, and distribution across the landscape. Project Design Criteria for maintenance of snags and downed wood is located in Chapter 2.

Skyline-Cable Systems

Using cables to suspend one or both ends of logs as they are pulled from the stand to the landing largely eliminates the potential for compaction and puddling within the stand. What remains, however, is the potential for detrimental soil displacement if one or both ends of the log are dragged across the ground from the stump to the landing. Full suspension (where the log is lifted entirely off the ground during yarding to the landing) and one-end suspension (where one end of the log is allowed to drag along the ground), are effective mitigations that are now regularly employed to minimize detrimental displacement, as well as the use of a predesignated skid trail or skyline corridor layout. Skyline systems typically result in approximately 5% or less detrimental soil conditions.

Aerial (Helicopter) Systems

Helicopter logging has the least impact of all logging systems on soil productivity. This is a form of full suspension, with no part of the log being drug across the ground, except for very short distances as logs are lifted off the ground from a central point between logs. Such logging eliminates any potential for equipment-generated detrimental soil displacement, compaction, or puddling and their attendant erosion effects. Helicopter logging does, however, require larger (greater than 1 acre), though fewer landings, with the associated compaction and displacement effects typically around 2%.

Activity Fuels Treatments

Activity fuels treatment refers to the slash and accumulated fuel resulting from the proposed density management treatments. Activity fuels treatments can include whole tree yarding or leave tops attached and landing pile burning. Fuel management treatments include: hand piling and burning, machine piling and burning, and jackpot burning. Other treatments proposed is the utilization of the removed slash, such as in the form of woodchips.

Project Design Criteria and Mitigation Measures that have been designed for the Chetco Bar Fire Salvage Project, including applicable best management practices (BMPs) in the National Core BMP Technical Guide (USFS 2012), as well as Regional and Forest level Standards and Guidelines, have influenced the planning of fuels treatment activities during project development, and would be implemented to minimize impacts of fuels treatments on soil productivity.

Forest Mycorrhizal Associations

Mycorrhizal fungi are an important component for survival and growth of tree species in the Pacific Northwest. These mutual and symbiotic fungi species use their fine mycelial strands to penetrate the root tips of trees. The trees provide energy to the fungus in the form of sugars and the fungus provides nutrients and water to the tree. The fine mycelial strands increase the surface area of nutrient collection and provide an important soil link for forest trees. Much of the biomass of mycorrhizal fungi resides in the top 4 inches (10 cm) of soil—a region likely to be affected by forest fire—the implications of fire induced changes in the mycorrhizal community could be significant to post-fire forest recovery and productivity (Fire Science Brief, 2009). Furthermore, according to the Chetco Bar Fire BAER Soils report (2017), a loss of soil nutrients and microbial communities may be expected, with these adverse effects increasing by soil burn severity class. Harvest treatments such as clearcut harvest, followed by machine piling can have greater impacts especially if all host trees are removed, there is a high amount of ground disturbance, and introduced grass species are allowed to dominate the site. However, according to studies by Barker et. al. (2013), greater impact to mycorrhizal fungi community assembly on regenerating seedlings are seen from wildfire than clearcutting and undisturbed forest. Treatments proposed in all action alternatives are mostly salvage logging operations, however project design criteria and best management practices, such as limiting the amount of detrimental soil disturbance to 15% or less, including roads and landings, operating in dry soil moisture conditions, and identifying skid trails, temporary roads, and landings prior to implementation would limit the high amount of ground disturbance. In addition, within the Chetco

Bar Fire Salvage Project Area Boundary the soil burn severity at the unburned and low severity classes would for the large part be outside the project footprint leaving live trees and dying host trees thereby ensuring the vigor and persistence of forest mycorrhizal species.

Post-fire fungi, or fungi that fruit following wildfire or eruption disturbances also serve as soil stabilizers, restoration of habitat, recovery of damaged plants or replacement of dead vegetation, decomposers of woody debris, and binding soil aggregates through mycelial networks to improve water and air filtration (Claridge et. al. 2009).Post-fire fungi were noted during field observations in the project footprint, and may help to aid against soil erosion while vegetation recovers in sites not disturbed by salvage logging operations.

Road Maintenance

Existing system roads are considered a long-term commitment of the soil resource to something other than soil productivity. The use of existing system roads during implementation of this project would not result in a change to the current condition of the soils that are committed to supporting the transportation system. However, where system roads have been closed for a period of years, some level of road maintenance would be necessary to make them suitable for treatment access. Road maintenance activities includes: removing danger trees, roadside brushing, culvert and ditch cleaning, resurfacing roads, and blading/reshaping road (see Chapter 2 for the full list of activities). Nonetheless, soil is compacted and short-term erosion from newly exposed soils is likely.

Temporary Roads and Landings

Construction of temporary roads (and their associated landings) detrimentally compacts soils and contributes to erosion by allowing water to run overland rather than naturally infiltrating at the point of raindrop impact. Roads are an example of detrimental soil compaction with adverse indirect impacts on water movement pathways. Properly designed and constructed roads (including temporary roads) require structures for channeling this now-redirected water flow to desired locations. Temporary roads and landings are expected to have an irretrievable reduction in soil productivity since they are bladed (soil is mixed and displaced) and compacted. Once rehabilitated, the hydrologic function of the soil profile may be re-established, but the soil profile in relation to organics and nutrient cycling is modified to a degree that may take many decades to return to the productive state of the undisturbed forest soils adjacent to it. Landings also, with their likely deep compaction, and soil mixing from construction and recurrent disturbance are expected to cause an irretrievable decrease in soil productivity. Nonetheless, their use is temporary, with the expectation that following use they would be returned to the highest degree of productivity reasonably achievable.

Existing legacy templates would also be used to construct temporary roads, and is largely what is proposed for all Action Alternatives. By using these routes as temporary roads where feasible during project implementation, instead of creating new temporary roads, the area of new detrimental soil disturbance would be minimized. The Siskiyou National Forest Plan establishes that no more than 15 percent of an activity area should be compacted, puddled, or displaced upon completion of a project (including permanent roads and landings).

Alternative 1- No Action

No adverse impacts to soils related to this project would occur under Alternative 1, as no ground-disturbing or road management activities (road maintenance) would be implemented. The existing conditions resulting from the Chetco Bar Fire would persist. This alternative would not alter the current erosion and landslide potential and would retain the same amount of coarse woody debris, although more of the coarse woody debris would fall to the ground and come in contact with the soil surface. Over time, organic matter would increase where high burn severities eliminated the surface litter and duff. Mycorrhizal fungi would continue to recover where the fire burned at high severity. This would increase water holding capacity on the site over time. As vegetation resprouts, nutrient cycling would increase and litter layers would restablish and soil productivity trend would move towards pre-fire levels.

Alternative 2 and 3- Direct and Indirect Effects to Soil and Site Productivity

The direct and indirect effects for both Action Alternatives are analyzed together because effects are not expected to differ between the two alternatives. The effects of treating in managed stands only do not change the effects from harvesting systems, temporary roads, landings, activity fuels treatments, and haul roads; the difference would be in the amount that could be potentially detrimentally disturbed since less acres would be treated, and therefore less connected actions (i.e. temporary roads, landings, and skid trails) would be constructed in Alternative 3.

Compaction, displacement, rutting, severe burning, surface erosion, loss of surface organic matter, and mass failures can all reduce site productivity. The main effects from the proposed action would be soil disturbance from salvaging, skidding, temporary roads, landings, and transporting logs. Proposed activities have the potential for both short and long term effects. However, soil productivity would be maintained since project-created soil disturbance would be short term and detrimental soil disturbance (DSD) below the thresholds where long-term impairment is evident. These disturbance types and the criteria used to define when a disturbance results in a detrimental soil condition are defined in the Siskiyou National Forest LRMP and the US Forest Service Manual (Region 6 Supplement No. 2500-9801).

Since existing system roads are considered a long-term commitment of the soil resource to something other than soil productivity, maintenance and reconstruction would have no effect to the current condition of the soils that are committed to supporting the transportation system. During maintenance and reconstruction activities, some temporary and short-term soil erosion could occur. Best management practices and mitigation measures have been developed that are highly effective at minimizing these effects, and would be implemented to greatly minimize erosion and the movement of sediment from these activities. Any potential effects are expected to be localized and short-term in duration.

Logging method and season of harvest are the dominant variables that determine the amount of detrimental disturbance that is likely to result from harvest activities. Table 7, below, provides an estimate of the maximum amount of detrimental disturbance that could potentially occur with each harvest system, per Action Alternative. However, implementation of Project Design Criteria and Mitigation Measures, such as limiting use of vehicles and equipment to dry soil conditions, or reuse and designation of skid trails before implementation, is expected to result in less than the estimated acreages actually resulting in detrimental disturbance (in particular displacement and compaction), since these measures are designed to limit or reduce the overall impacts of the actions to prevent the creation of a detrimental condition. Furthermore, design measures, such as not allowing new disturbance and requiring rehabilitation treatments (i.e. subsoiling), also have been developed based on the current estimated detrimental disturbance conditions within units listed in Table 5. Harvest units identified in Chapter 2 will have these mitigation measure to assure Forest Plan S & G's will not be exceeded, and that soil quality would move towards a net improvement. Estimates for ground based harvest systems is 15 percent DSD. The estimate for DSD from skyline harvest systems is five percent. The DSD estimate for aerial harvest systems is two percent. DSD estimates include average impacts from travel off of designated roads and log landing construction.

Effects to soil from new temporary road construction in Alternative 2 are expected to span an average width of 25 feet wherever roads are built. This estimate is based on the assumption of a running road surface 12–15 feet wide and an additional 3–6 feet, cleared of vegetation, on each side of the road, where the soil would likely be displaced and the organic litter layer disturbed and/or removed. Approximately, 1.3 miles of new temporary road construction would be constructed, which would result in an estimated of 4 acres being detrimentally disturbed through compaction and displacement. This effect would be mitigated as these roads, following use, would be returned to the highest degree of productivity reasonably achievable. In addition, the majority of these new temporary road segments would be constructed over relatively flat terrain. However, new temporary road segments include soils that contain higher clay content in the subsoil, and thus have a higher susceptibility to compaction and rutting if constructed and driven over in wet soil conditions. Restoration of soil productivity on these sites would be more successful if operations are limited to dry soil moisture conditions, when soil strength is greater to withstand the weight of equipment. No new temporary roads would be constructed in Alternative 3.

Approximately 12.2 miles of temporary road would be constructed on existing legacy templates for Alternative 2 and 9.4 miles for Alternative 3. There would be no detrimental disturbance associated with the use of these templates as soils have been compacted and displaced from past use. These actions have the potential to create short-term and localized erosion from newly loosened and exposed soils.

Forest Service Roads 1400. 092, 1107.576, and 1107.570 lists non-system, historic road prisms planned for temporary access in the proposed action. Reconstruction of these non-system roads for management activities would reverse soil recovery gained since decommissioning, however more effective methods of rehabilitating these roads than were employed historically may be implemented post-harvest, such as recontouring to natural contour, removing culverts, and subsoiling. .

Activity-generated slash piled along roadsides and in landings would be removed when effective groundcover (85%) needs and large woody material, for soil productivity, have met SLRMP standards and guidelines. Activity generated slash would be machine piled and burned, hand piled and burned, or removed as biomass, such as woodchips. Treatment of slash is incorporated in the estimated DSD in Table 7.

Effects to mycorrhizal fungi from salvage logging in burned areas would reduce the levels of microbial communities where ground disturbing operations would occur. Timber harvest and soil compaction can alter forest soil productivity by reducing organic matter; which ectomycorrhizal diversity may also be tied to the diversity of organic matter on the forest floor (Amaranthus et. al. 1996).However, this is anticipated to occur only on designated skid trails, temporary roads and landings. Maintenance of the soil organic layer would be achieved in all of the action alternatives. Tractor harvest operations will be on designated skid trails and landings which are largely pre-existing due to multiple entries from prior harvest. Operating on dry soil moisture conditions will also reduce soil compaction and effects to mycorrhizal fungi.

The detrimental soil conditions Standards and Guidelines are the same across all management areas and land allocations, and therefore no distinction between land allocations is made in estimating the acres of detrimental disturbance. Additional Project Design Criteria excluding new disturbance in Riparian Reserves, for example, no new temporary road or landing construction limits detrimental disturbance adversely affecting soil infiltration capacity (i.e., detrimental compaction), and would result in even less total area experiencing detrimental disturbance from project activities.

Table 7. Total estimated acres of new detrimental soils disturbance.

	Alternative 1	**Alternative 2**	**Alternative 3**
Ground-based harvest system (est. 15%)	0 acres	93 acres	50 acres
Skyline harvest system (est. 5%)	0 acres	119 acres	62 acres
Aerial harvest system (est. 2%)	0 acres	22 acres	6.0 acres
New Temporary Roads	0 acres	4.0 acres	0 acres
Totals	**0 acres**	**238 acres**	**118 acres**

Alternative 2 and 3 -Direct and Indirect Effects to Soil Stability and Erosion Hazard Potential

The direct and indirect effects for both Action Alternatives are analyzed together because effects are not expected to differ between the two alternatives. The effects of treating in managed stands only do not change the effects from harvesting systems, temporary roads, landings, activity fuels treatments, and haul roads; the difference would be in the amount that would have the potential for erosion and mass failure from the proposed project footprint since less acres would be treated, and therefore less connected actions (i.e. temporary roads, landings, and skid trails) would be constructed in Alternative 3.

Unstable areas were preliminarily identified using the Slope Stability and Erosion Risk mapping model, described above. All potential unstable areas were excluded from the salvage harvest units in all Action Alternatives. If additional unstable areas are identified during layout, the area would be excluded from harvest and the appropriate riparian reserve buffer would be added. No harvest activities would occur in these areas. Indicators of unstable areas include: steep (>65%) concave slopes; slumps, draws, and headwalls; past landslide locations; and obvious soil movement areas (typically indicated by curved and/or pistol butted trees, soil creep, tension cracks, etc.). Slopes less than or equal to 30 percent would be allowed to be tractor logged, otherwise skyline or helicopter harvest systems are to be prescribed in order to avoid using logging equipment on steep slopes, which would avoid potential for slope failures. In addition, it is not expected that harvest would impact root strength, which aids in slope stability, since activities would only be cutting dead, dying, or damaged trees. When trees die or are cut, the roots die and decay, resulting in a decline of reinforcement by the roots; approximately 50% of the original root reinforcement is lost within 2 years after deforestation, with 90% gone within 9 years (Ziemer 1981a). Furthermore, as stated in existing conditions, resprouting of surface vegetation (i.e. understory, shrubs, and forbs) has been observed in all classifications of soil burn severity. In particular, tanoak was noted as one of the major species returning post fire, which maintains a live root system despite being burned over, which can make up for the loss of conifer root systems and improve stability and erosion concerns (refer to the Silviculture assessment for further information on vegetation composition.).

The project footprint has been mapped by soil map unit and rated for relative disturbances based on inherent soil properties. Table 8 is an erosion hazard assessment based on the soil map unit to determine erosional characteristics of the project units and temporary roads. This assessment was used to develop project design criteria to minimize erosion potential, such as scattering generated slash to 85% effective ground cover post operations, designating skid trails, and limiting off road harvest to dry soil moisture conditions. Mass wasting, erosion hazard (off road/ off trail), and erosion hazard (road/trail) ratings were evaluated for the soil types overlapping within the proposed harvest units temporary roads constructed.

Table 8. Acres of project footprint activities on relative disturbances for action alternatives.

Hazard	**Alternative 1 (acres)**	**Alternative 2 (acres)**	**Alternative 3 (acres)**
Temporary roads Erosion Hazard (Road/Trail)	0	52	42
Harvest Units Erosion Hazard (Off-Road, Off-Trail)	0	2, 640	1, 201
Mass Failure (SRI Landtypes 8 and 9)	0	902	543

Erosion hazard (road/trail) was rated as severe or very severe for all temporary roads under Alternative 2 and under Alternative 3. Erosion hazard (off road/off trail) was rated as high on 2, 640 acres (64%) of proposed units under Alternative 2 and 1, 201 acres (64%) of units under Alternative 3. Under Alternative 2, approximately 902 acres (22%), is considered high mass failure potential. Under Alternative 3, approximately 543 acres (29%) is considered as high mass failure potential. However, project design criteria has been developed to avoid potentially unstable or unstable terrain. During layout and implementation these areas will be excluded from all treatment activities to greatly reduce the potential for mass failures, and therefore no change in mass failure potential is expected from the action alternatives.

Soil erosion hazards used to assess the effects of the alternatives on erosion potentials indicate an overall increase of erosion potential for each of the action alternatives. However, Biscuit monitoring studies from 2002 to 2005 concluded that needle cast and leaf litter appeared to have the greatest effect on erosion vs. accumulation, which has been observed in many of the low and moderate burn severity sites; and after three winter seasons, there did not appear to be a significant increase in soil movement due to the fire (GSA/Geocorps, 2005). Additionally, project design criteria to reduce the potential for erosion include the following: limiting the amount of skid trails and landings; fully decommissioning all skid trails, temporary roads, and landings on erosive soil map units; and placing large woody material and scattering slash as effective groundcover post operations (complete list of project design criteria for soils in Chapter 2

The proposed temporary roads would be located on ridgetops and upper slopes, and only short, discontinuous portions would require some form of excavation. All temporary roads would be decommissioned after use, and rehabilitation treatment would be implemented to aid in soil stability. An increased number of water bars that have a gradient of 10 percent or more or the addition of slash material to the road bed would be used as necessary to reduce erosion while the road is in use. Even if small segments in these roads cut into the subsurface material and some erosion does occur, the likelihood of sediment delivery to streams would be minimal, because temporary roads would be located on ridgetops far from stream channels.

Alternative 2 and 3- Cumulative Effects

Cumulative effects consist of the impacts from all past, present, reasonably foreseeable future and proposed activities effects overlapping in time and space. The spatial scope for cumulative effects is the individual salvage harvest units (variable acres) and associated temporary roads. Units proposed for harvest treatment were reviewed for disturbances (i.e. temporary roads, landings, skid roads, and yarding corridors) using aerial photos and GIS corporate data identifying past management actions dated back to 1994 in Google Earth. The effects from past activities were quantified and determined if existing levels of detrimental disturbance exceeded the Region 6 Soil Quality Guidelines.

Past actions in these areas that could have added to detrimental soil disturbance include timber harvest (stand clearcuts and thinning) identified in Table 5 and related burning/wildfires from 1954 thru 2018. Fire suppression activities, such as manual and machine-based building of fire breaks, can also disturb soil and increase erosion potential. However, these activities probably occurred over a relatively small area of the proposed treatment units. In addition, fire lines are water barred and have woody debris applied to control erosion. Ongoing and upcoming projects within the project footprint include forest restoration, firewood cutting, invasive weed control, and roadside danger tree abatement. Although there are several disturbances in the project footprint, the Chetco Bar Fire is the largest factor that could affect DSD and erosion. However, 85 percent effective ground cover is required post operations and will mitigate potential soil erosion and loss of organic matter and nutrients by increasing the amount of woody debris in the project footprint over existing conditions, and add vegetative debris to the ground surface at a greater rate than what would occur under natural conditions. In addition, following salvage harvest the project footprint will be surveyed for natural regeneration. In sites where natural regeneration is not viable, tree planting would be manually planted to achieve stocking levels consistent with management objectives, mitigating soil effects from areas burned at high soil severity.

Roadside danger tree abatement would be harvesting potentially 62 acres under alternative 2, and 31 acres under Alternative 3 which may overlap in time and space within the project footprint. Layout of roadside danger tree abatement has not been completed within the project footprint, and therefore these numbers are likely to increase. Roadside danger tree abatement is likely to end in 2019.Prior to and post-implementation, monitoring would be performed to determine if selected units were meeting Region 6 Soil Quality Standards, and is described as such in the PDCs described in Chapter 2..The Sale Administrator would monitor all units during management activities to assure that operating conditions are adequate to minimize cumulative effects to the soil resource.

Table 9 displays the total acres of detrimental soil disturbance expected from the proposed activities. The action alternatives are designed to reduce the amount of detrimental soil disturbance by implementing the design features described in *Chapter 2*.

Table 9 Detrimental soil disturbance acres by action alternative.

Description	Alternative 2	Alternative 3
Acres of Detrimental Disturbance from Past Activities	113.7	88.6
Acres of Detrimental Disturbance from Proposed Activities	238.0	118.0
Acres of Cumulative of Detrimental Disturbance	351.7	206.0

Management Direction and Consistency

• Siskiyou NF Forest Plan Management Direction – Forest-wide standards and guidelines for soil and water resources, (USDA 1989, pages. IV-44 through IV-48) are:

○ Ensure land management activities are planned and conducted to maintain soil productivity and stability. The S&Gs specific to the Soils resource are listed below:

- The total area of detrimental soil conditions should not exceed 15 percent of the total acreage within the activity area, including roads and landings (S&G 7-2, page IV-44) (Siskiyou National Forest, 1989)
- Mineral soil exposure guidance (specific to Chetco Bar Fire project footprint, minimum 85 percent effective ground cover) (S &G 7-4)
- Avoiding mass movement (S&G 7-7)
- Retention of large woody material (S&G 7-8)

• Design or modify all management practices as necessary to protect land productivity and stability.

•The General Water Quality Best Management Practices (USDA-FS 1988) document is referenced as a Best Management Practices guidance document in the Siskiyou LRMP (USDA 1989, Page IV-47), however the National Core BMP Technical Guide (USDA FS, 2012) now supersedes the document and is used to develop to project design criteria and best management practices. Best Management Practices (BMPs) are to be used in the planning and implementation of timber sale and associated activities. Specific BMPs for this project are described in Chapter 2

•Regional guidance is available from the Region 6 Forest Service Manual for Soil Management *Forest Service Manual (FSM) 2550 – Soil Management WO Amendment 2500-2010-1, (USDA 2010)* and *FSM 2500 – Watershed Protection and Management, Region 6 Supplement No. 2500-9801 (USDA 2009).*

Forest Plan guidelines are met by all alternatives by conducting this environmental analysis, designing logging systems to minimize disturbance, and implementing soil and water conservation practices.

References Cited

Amaranthus, Michael; Page-Dumroese, Debbie; Harvey, Al; Cazares, Efren; and Bednar, Larry E.; 1996. Soil Compaction and Organic Matter Affect Conifer Seedling Nonmycorrhizal and Ectomycorrhizal Root Tip Abundance and Diversity; USDA, Pacific Northwest Research Station; PNW-RP-494

Atzet, T., R.F. Powers, D.H. McNabb, M.P. Amaranthus, and E.R. Gross. 1989. Maintaining long-term forest productivity in Southwest Oregon and northern California. P. 185-201 *in* Maintaining the long-term productivity of Pacific Northwest forest ecosystems, Perry, D.A., et al. (eds.). Timber Press, Portland, OR.

Barker, J.S. Simard, S.W. Jones, M.D. Durall, D.M. 2013. Ectomycorrhizal fungal community assembly on regenerating Douglas-fir after wildfire and clearcut harvesting. P: 1179-1189 in Oecologia (2013) 172

Claridge, A. W. Trappe, J.M. Hansen, K. 2009. Do fungi have a role as soil stabilizers and remediators after forest fire? P: 1063 – 1069 in Forest Ecology and Management 257 (2009).

(DOGAMI) Oregon Department of Geologic and Mineral Industries. 2009. Oregon Geologic Data Compilation (OGDC) – Release 5.

Floch, R.F. 1988. Shovel logging and soil compaction: A case study. Masters Thesis, Oregon State Univ., Corvallis, OR. May 1988.

Goodman, D.M. and J.A. Trofymow. 1998. Comparison of communities of ectomycorrhizal fungi in old-growth and mature stands of Douglas-fir at two sites on southern Vancouver Island. Can. J. For. Res. 28: 574-581.

GSA and Geocorps. 2005. Monitoring: Soil Erosion After the Biscuit Fire. 1 pg.

Jenson, S.K. and J.O. Domingue. 1988. Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. *Photogrammetric Engineering and Remote Sensing*. Vol. 54, No. 11, November 1988, pp. 1593-1600.

Joint Fire Science Program. Fire Science Brief. 2009. The Forest, the Fire and the Fungi: Studying the Effects of Prescribed Burning on Mycorrhizal Fungi in Crater Lake National Park. https://www.firescience.gov/projects/briefs/03-3-2-05_FSBrief38.pdf. Accessed 2018.

Keslick, J.A. Jr. 1997. Fact Sheets: “Dozer” blight. One absorptive structure, mycorrhiza. How to kill a tree.

Meyer, L.C. and M.P. Amaranthus. 1979. Siskiyou National Forest Soil Resource Inventory. 258 pg.

MacDonald, K. and Ochoa, L. 2017. Chetco Bar Fire BAER Soil Resource Assessment. U.S. Forest Service, Rogue River- Siskiyou National Forest, Gold Beach, OR.

Page-Dumroese, Deborah S., Ann M. Abbott, and Thomas M. Rice. 2009. Forest Soil Disturbance Monitoring Protocol, Volume I and Volume II. GTR-WO-82a, 82b. U.S. Department of Agriculture, Forest Service.

Park, S.J., K. McSweeney, and B. Lowery. 2001. Identification of the spatial distribution of soils using a process based terrain characterization. Geoderma 103:249-272.

Pennock, D.J., B.J. Zebarth, and E. De Jong. 1987. Landform classification and soil distribution in hummocky terrain, Saskatchewan, Canada. Geoderma 40:297-315.

(USFS) United States Department of Agriculture. Forest Service. 1989. Land and Resource Management Plan, Siskiyou National Forest. Region Six.

United States Department of Agriculture, Forest Service, and United States Department of the Interior, Bureau of Land Management. 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl. USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

U.S. Department of Agriculture, Forest Service. 1998. FSM 2520 – Watershed Protection and Management, R-6 Supplement No. 2500-98-1. Region 6, Portland, Oregon. 6 pg.

U.S. Department of Agriculture, Forest Service. 2010. FSM 2500 – Watershed and Air Management, Chapter 2550 – Soil Management, Amendment No. 2500-2010-1. Effective November 23, 2010. National Headquarters (WO), Washington D.C. 20 pg.

U.S. Department of Agriculture, Forest Service. 2012. National Best Management Practices for Water Quality Management on National Forest System Lands, Volume 1: National Core BMP Technical Guide. FS-990a. April 2012. 165 pg.

USDA, Forest Service, Pacific Northwest Region, 1996, Chetco River Watershed Analysis: iteration 1.0. Brookings Oregon, Siskiyou National Forest, Chetco Ranger District

USDA, Forest Service Pacific Northwest Region, 1998, Pistol River Watershed Analysis, iteration 1.0, Brookings Oregon, Siskiyou National Forest, Chetco Ranger District

USDA NRCS (USDA Natural Resources Conservation Service). 1995b. Soil Survey of Curry County, Oregon. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx) . Accessed 2018.

Ziemer, R.R. 1981a. Root Strength (Botany), 1981 McGraw-Hill Yearbook of Science and Technology

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